Nuclear emergency modelling at the Norwegian Meteorological Institute

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Abstract. The Severe Nuclear Accident Program (SNAP) model has been developed at the Norwegian Meteorological Institute (met.no) for simulating atmospheric dispersion of radioactive debris from nuclear accident and became operational already in 1995. Since that time SNAP has been continuously improved and developed in close collaboration with the Norwegian Radiation Protection Authority (NRPA), who is the main model user. Today, SNAP can be used in two ways, both for nuclear accident and explosion. First, the authorised personnel of NRPA can start the model remotely by submitting the input file to SNAP server at met.no. After the model run is finished the results are immediately sent back to NRPA and analysed using the ARGOS system. The second way is the action of a meteorologist on duty at met.no who can start the model and then analyse the results. In both ways the system is operational 24 hours a day. SNAP has proved to be fast, efficient and robust over the years. Here, we present the SNAP model and its operational applications.

1. INTRODUCTION

There are three main kinds of input necessary for modelling atmospheric dispersion of radioactive debris, in case of nuclear emergency: 1) specification of the source term, 2) dispersion model and 3) meteorological input data for the time of nuclear accident/explosion and for at least next 48 hours. In the frame of co-operation between NRPA and met.no, the source term is usually developed at NRPA. The dispersion model SNAP and meteorological input data are available at met.no. Meteorological input is computed four times a day by the operational Numerical Weather Prediction (NWP) model, Simulation of atmospheric dispersion of radioactive debris is performed at met.no using the SNAP model. The SNAP run can be activated either remotely from NRPA or manually by the synoptic on duty at met.no. More details of the operational setup and operation of the SNAP model at met.no are given in Section 3.

2. SNAP DISPERSION MODEL

The Severe Nuclear Accident Program (SNAP) model has been developed at met.no for simulating atmospheric dispersion of radioactive debris, first from

nuclear accidents and then from nuclear explosions. In addition to radioactive applications, SNAP has been also used to simulate large fires and atmospheric dispersion of volcanic ash from Eyafjallajökull eruption in 2010 [1]. SNAP is fully operational at met.no at present, both for nuclear and volcano applications, but here we will concentrate on nuclear emergency only.

SNAP is a Lagrangian particle model in which the emitted mass of radioactive debris is distributed among a large number of model particles. After the release, each model particle carries a given mass of selected pollutant which can be in the form of gas, aerosol or particulate matter. A model particle in this approach is given an abstract mathematical definition, rather than a physical air parcel containing a given pollutant. It is used in SNAP as a vehicle to carry the information about the pollutant emitted from the source. The model particle is not given a definite size and can be not subdivided or split into parts. On the other hand, the mass or activity carried by the particle can be subdivided and partly removed during the transport.

As in case of many other models, the development of SNAP started after the Chernobyl accident which occurred in April 1986. The first, preliminary model version was ready in 1994 [2] and it became fully operational at met.no in December 1995 [3]. This operational version of SNAP was tested against tracer measurements in the European Tracer Experiment (ETEX) [4] and then improved [5]. In 1996, SNAP was compared with two other models, one of Lagrangian type, NAME model from UK meteorological Office and one Eulerian EMEP model modified for radioactive pollution from the Norwegian Meteorological Institute [6]. These three models produced similar results concerning the location of radioactive cloud, but the differences in concentrations were larger. The SNAP model was compared with many other models and tested on measurements available from the tracer releases not only in the frame of ETEX experiments, but also ATMES experiment [7].

In the frame of joint project between met.no and NRPA, SNAP was used in analysis of potential threat from hypothetical accident in Kola nuclear power plant [8]. The results of SNAP calculations indicated that, in case of accident the radioactive cloud can reach Northern Norway already after six hours and Oslo after two days from the accident start.

In the early versions of the SNAP models only small (diameter below 1 μm) particles were taken into account in the model equations. Some measurements, performed by University of Life Sciences after Chernobyl accident, showed that in certain cases also much larger (of the order of 20 μm) particles, so called hot particles were transported for long distances reaching Norway. Therefore, parameterization of particles with arbitrary diameter and density was introduced into the SNAP model and this model version was applied to simulate the Chernobyl accident again [9,10]. This version was also applied for simulating the potential release from Kola once again, this time focusing on radioactive particle of different size and density [11]. Introduction of arbitrary particles into the SNAP equations made it possible to create a SNAP version for nuclear explosion [12, 10] which is currently operational at met.no.

SNAP has been an active member of the ENSEMBLE project for the last 10 years [12] with the possibility of comparing SNAP results with more than 20 other models in the same grid system.

Recently, in March 2011, SNAP was used for simulating atmospheric dispersion of I-131 and Cs-137 from the accident in Fukushima I NPP in Japan. For this purpose the model grid system was extended to cover most of the Northern Hemisphere as well as the forecast time from 48 hours to 10 days.

2.1 Model domain and vertical structure

The SNAP model is flexible concerning, both model domain and meteorological data. The spatial and vertical structure of the standard SNAP model domain is in fact defined by the meteorological input. For the present operational version of SNAP, the results of the High Resolution Limited Area Model (HIRLAM) [13] are used as the meteorological input. This NWP model is currently operational at met.no and it is being run 4 times a day, to produce 66 hour forecasts starting at 00, 06, 12 and 18 UTC. Computational domain of the SNAP model and at the same time of HIRLAM model is shown in Fig. 1. The territory of Norway is located in the centre of the model domain. The model grid system consists of 864 nodes in x-direction and 698 nodes in y-direction. Vertical structure consists of 60 levels in η-coordinates.

The SNAP model can be run in two modes. In the graphical mode, the selected SNAP results are shown on the screen during the model run. These results include the locations of model particles on the map within the model domain, which are continuously updated. In the batch mode, no graphics is shown on the screen, but the model execution is much faster. An example of screen display during the SNAP run for radioactive pollutants is shown in Fig.1.

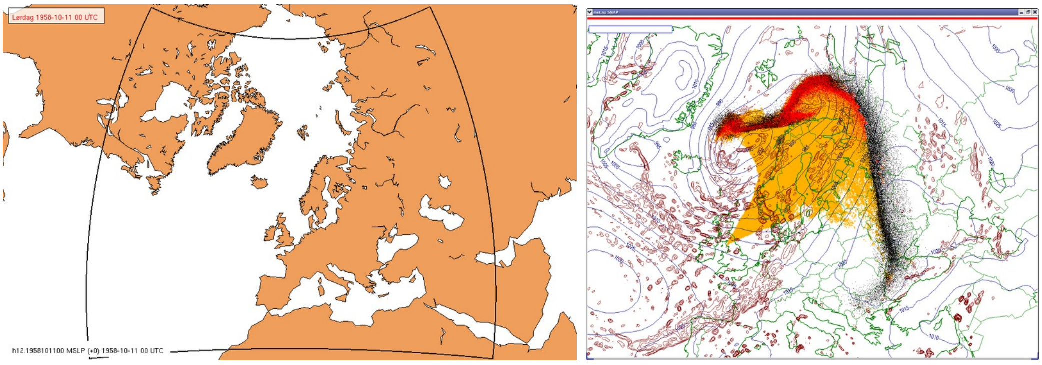

Fig. 1. Standard computational domain of the operational SNAP model at met.no and on-line screen view of SNAP results for the model operator at met.no.

The isolines of pressure and precipitation are shown together with the model particles in Fig. 1. Different colours are used for marking the model particles. Those affected by precipitation are red and those in dry environment are black. A gold colour is used to show the contaminated part of the model domain where the radioactive debris is deposited in dry or wet process.

3. OPERATIONAL SNAP APPLICATIONS

Today, SNAP can be used in two ways. First, the authorised personnel of NRPA can start the model remotely by submitting the input file to SNAP server at met.no. After the model run is finished the results are immediately sent back to NRPA and analysed using the ARGOS system. The second way is the action of a meteorologist on duty who can start the model and then analyse the results. In both ways the system is operational 24 hours a day. SNAP has proved to be fast, efficient and robust over the years.

3.1 Simulation of nuclear accident in the standard model domain

In case of nuclear accident, the SNAP model requires a specification of the input file, both for remote automatic application and manual start directly from met.no. However, the structure of this input file is slightly different for direct and remote application.

The input file for both applications includes the following basic information: 1) geographical co-ordinates of the accident location, 2) exact time of the accident start which the same a release start, 3) radius of the cylinder where the radioactive debris is spread initially, 4) the height of the base of cylinder, 5) the height of cylinder top and 6) the number of components released, 7) specification of individual properties of each component released (e.g. name, time profile of release from the beginning to the end of accident, density, diameter for particles). With this input file, SNP is run in a relatively fast batch mode. The time from submission of the input file at NRPA to reception of the output file at NRPA is of the order of 10-20 minutes. The direct simulation at met.no requires approximately the same time. In both cases there an additional time needed for generating the final graphical output from the model results. The simulation is significantly longer 1-2 hours in case of SNAP application in the hemispheric grid, with the release source located far away from Norway, like in the case of Fukushima accident.

An example of the results of SNAP simulation is shown in Fig. 2 in the form of accumulated concentration fields of Cs-137, released from the hypothetical accident on the ship carrying nuclear waste in the coast of Norway. The map presented in Fig. 2 on the left was generated by the ARGOS system at NRPA. The map on the right side of Fig.2 was generated using the DIANA system at met.no.

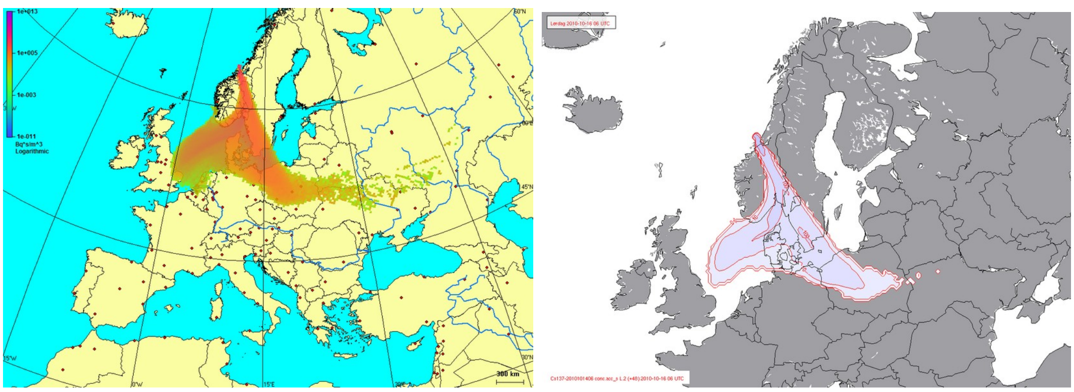

Fig. 2. An example of the post-processing of SNAP model results at NRPA using the ARGOS system (left) and DIANA graphics at met.no (right).

3.2 Simulation of Fukushima accident

An extension of the model domain to the entire Hemisphere was necessary for the simulations of atmospheric dispersion of I-131 and Cs-137 released during the Fukushima accident in March 2011. The simulation was performed in real time during the accident with the forecast time extended up to 10 days compared to the standard version of SNAP.

The source term for Fukushima accident was provided by NRPA and originally only dispersion of I-131 was simulated. The results of this simulation in the form of accumulated concentration over the Northern Hemisphere are shown in Fig. 4.

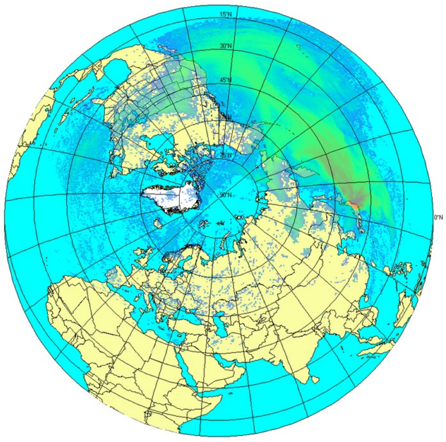

Fig. 4. An example of the post-processing of SNAP model results at NRPA using ARGOS program.

It was interesting to notice that when according to model results, the radioactive cloud came after 10 days of the transport to Norway, the I-131 air concentration measured in Norway by NRPA has clearly increased above the normal level. It was an encouraging result concerning SNAP ability to simulate the movement of radioactive cloud in case of an accident.

3.3 Simulation of nuclear detonation

The source term for nuclear explosion is determined in SNAP by the explosive yield. Ten classes of radioactive particles with the diameter range from 1 to 250 μm and equal distribution of radioactivity are assumed to be the product of the explosion. They can be initially distributed either in the cylinder or in the mushroom consisting of two cylinders with the parameters dependent on the explosive yield. An example of the model results from the simulation of hypothetical nuclear explosion in Scotland is shown in Fig. 5. The dry deposition field is relatively regular in structure compared to wet deposition field, which depends on irregular precipitation pattern.

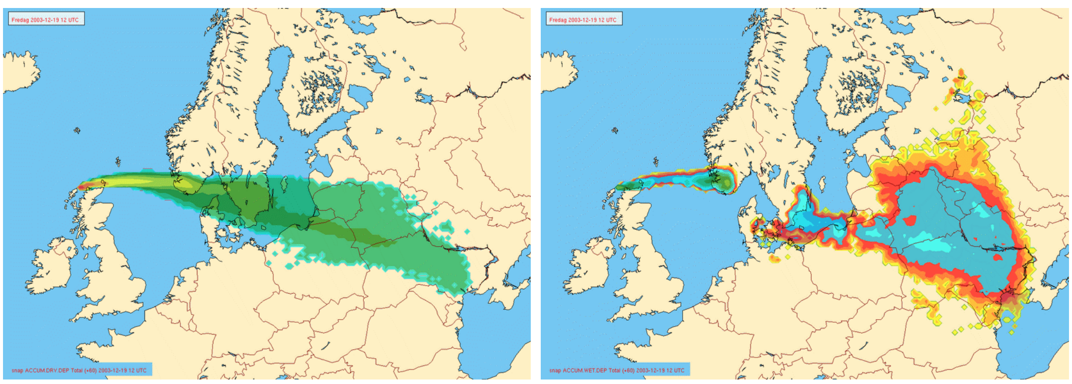

Fig. 5. An example of SNAP results for simulation of nuclear detonation. Dry deposition on the left and wet deposition on the right.

4. CONCLUSIONS

At present (April, 2010), SNAP model is fully operational at met.no for the simulation of atmospheric dispersion of radioactive debris from nuclear accidents and nuclear explosions. The model has been tested in the ATMES and ETEX experiment showing relatively good agreement with observed tracer concentrations. It can be used both directly at met.no and remotely from NRPA. In 2011, model applications have been extended both, in space – to hemispheric scale and in time – to 10 days forecast. SNAP has proved to be robust and very useful, both for decision makers and scientist.

Acknowledgements

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References

1. J. Bartnicki, H Haakenstad, Ø. Hov. Met.no report 15/2010. Norwegian meteorological Institute.

2. J. Saltbones and A. Foss, in: Preprints of the XIX Nordic Meteorologists Meeting, June 1994, Kristiansand, Norway (1994).

3. J. Saltbones, A. Foss, J. Bartnicki. Research Report No. 15. Norwegian Meteorological Institute. Oslo, Norway (1995).

4. J. Saltbones, A. Foss, J. Bartnicki, Systems Analysis Modelling Simulation 25, 263 (1996).

5. J. Bartnicki, J. Saltbones, in: Development and Application of Computer Techniques to Environmental Studies VI., edited by P. Zanetti and C.A. Brebia, Computational Mechanics Publications, Southampton, Boston, p. 17 (1996).

6. R.H. Maryon R.H., J. Saltbones, D.B. Ryall, J. Bartnicki, H.A. Jakobsen, E. Berge, UK Met Office Turbulence and Diffusion Note 234. UK Meteorological Office, Bracknell, United Kingdom (2006).

7. J. Saltbones, A.Foss, J. Bartnicki, Atmospheric Environment 32(24), p. 4277 (1998).

8. J. Bartnicki, J. Saltbones (1997) Analysis of Atmospheric Transport and Deposition of Radioactive Material Released During a Potential Accident at Kola Nuclear Power Plant. Research Report No. 43, Norwegian Meteorological Institute, Oslo, Norway.

9. J. Bartnicki, B. Salbu, J. Saltbones, A. Foss, O. Ch. Lind, Research Report No. 131. Norwegian Meteorological Institute, Oslo, Norway, (2001).

10. J. Bartnicki J., B. Salbu, J. Saltbones, A. Foss and O. Ch. Lind, in Preprints of 26th NATO/CCMS International Technical Meeting on Air Pollution Modelling and its Application, 26-30 May 2003. Istanbul Technical University, Istanbul, Turkey, p. 53, (2003).

11. J. Bartnicki J., B. Salbu, J. Saltbones, A. Foss, O. C. Lind, in Proceedings of 1st Joint Emergency Preparedness and Response/Robotic and Remote Systems Topical Meeting. February 11-16, 2006 Salt Lake City, Utah, USA, (2006).

12. S. Galmarini, R. Bianconi, W. Klug, T. Mikkelsen, R. Addis, S. Andronopoulos, P. Astrup, A. Baklanov, J. Bartnicki, J.C. Bartzis, R. Bellasio, F. Bompay, R. Buckley, M. Bouzom, H. Champion, R. D'Amours, E. Davakis, H. Eleveld, G.T. Geertsema, H. Glaab, M. Kollax, M. Ilvonen, A. Manning, U. Pechinger, C. Persson, E. Polreich, S. Potemski, M. Prodanova, J. Saltbones, H. Slaper, M. Sofiev, D. Syrakov, J.H. Sørensen, L. Van der Auwera, I. Valkama, R. Zelazny, Atmos. Environ. 38 (28), 4607 (2004).

13. P. Undén, L. Rontu, H. Järvinen, P. Lynch, J. Calvo, G. Cats, J. Cuaxart, K. Eerola, C. Fortelius, J.A. Garcia-Moya, C. Jones, G. Lenderlink, A. McDonald, R. McGrath, B. Navascues, N.W. Nielsen, V Ødegaard, Z Rodriguez, M. Rummukainen, R. Rööm, K. Sattler, B.H. Sass, H. Savijärvi, B.W. Schreur, R. Sigg, H The, A. Tijm, HIRLAM-5 Scientific Documentation, HIRLAM-5 Project. Available from SMHI, S-601767 Norrköping, Sweden, (2007).